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Microstructural Behavior of Interfaces in Hot Isostatically Pressed, Dual Alloy Combinations

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SUMMARY

Dual alloy combinations with potential use for turbine engine components were evaluated for microstructural stability. The combinations were MERL 76 and Low Carbon Astroloy, René 95 and Low Carbon Astroloy, René 95 and NASA-TRW-VIA. These nickel-base superalloys, produced from prealloyed powders, were combined by hot isostatic pressing. Samples were exposed at 870° C for 1500 hours in an accelerated test to simulate turbine engine service conditions. Other samples were exposed in a gradient furnace to temperatures reaching 1300° C. Neither treatment caused the formation of new metallurgical phases near the interfaces which were not present in the alloys. Gamma prime coarsening was noted after the prolonged exposure to 870° C.

INTRODUCTION

New technology has demonstrated that it is possible to combine, by hot isostatic pressing (HIP), two prealloyed powder metallurgy nickel-base superalloys (1). This allows the production of advanced dual alloy turbine disks in which the rim can withstand high rupture stresses up to 760° C, with a simultaneous improvement in the resistance to tensile and fatigue loading in the hub at temperatures of 400°-500° C. Dual alloy disk technology also offers an opportunity to conserve strategic materials not only by savings through powder metallurgy, but also by the use of alloys with low strategic element contents in those portions of the disks where their properties are adequate.

However, before dual alloy combinations can be used, it must be confirmed that the combining of two different compositions does not result in microstructural instabilities at their interface. This could manifest itself by the appearance of new phases during the HIP cycle, subsequent heat treatments or during engine operation. The research reported here addresses itself to this problem. Four alloys are included in the investigation: MERL 76 and René 95 are candidates for use in the hubs of dual alloy turbine disks, while Low Carbon Astroloy and NASA-TRW-VIA are suitable for the rims. The combinations evaluated were MERL 76 with Low Carbon Astroloy, René 95 with Low Carbon Astroloy, and René 95 with NASA-TRW-VIA.

Since new phases might result during the HIP cycle and solution treatments, exposure to a wide range of temperatures was effected in a gradient furnace. Prolonged use of some superalloys at elevated temperatures has been known to promote the formation of brittle, acicular phases, designated as sigma and mu. The alloy combinations were therefore exposed to 870° C for 1500 hours. The effect of this accelerated exposure treatment on the microstructure was determined at the interface of two alloy compositions and also in mixed powders, since powder mixtures are likely to occur and may even be desirable in actual parts.

MATERIALS AND PROCEDURES

The four alloys, MERL 76, René 95, Low Carbon Astroloy, and NASA-TRW-VIA, used in this work had been vacuum induction melted, cast, remelted and argon atomized. Analyzed compositions and sieve analyses are presented in table I.

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For some of the experiments mixtures of powders were prepared by blending equal quantities of MERL 76 and Low Carbon Astroloy, René 95 and Low Carbon Astroloy, René 95 and NASA-TRW-VIA.

Stainless steel cans with a rectangular base, measuring about 110x15 mm were filled with layers, about 15 mm thick, of powders as shown in figure 1. Each two-layer can contained two different alloys. In each four-layer can two alloys contacted each other and also a layer of their prepared mixture. The cans were closed with a stainless steel cover, evacuated and sealed by welding. The cans were hot pressed isostatically to 140 MPa at 1120° C for 4 hours.

After pressing, specimens were cut from all cans for examination of the microstructures in the as-HIP condition. Portions of the four-layer cans were exposed at 870° C for 1500 hours. Cans with two layers had the canning materials removed by grinding. These cans were heated to a maximum of 1300° C in a gradient furnace with the gradient parallel to the layers (see fig. 1). Readings taken from thermocouples along the gradient showed that at distances of 15, 40 and 60 mm from the hot end the temperatures averaged 1285°, 1220° and 1140° C, respectively.

MICROSTRUCTURAL EXAMINATION

Microstructures of as-HIP and heat-treated specimens were examined by optical and scanning electron microscopy. Ground and polished specimens were etched with Kalling's reagent for optical examination and with a solution of 33 percent hydrochloric acid, 33 percent acetic acid, 33 percent water, and 1 percent hydrofluoric acid for electron microscopy. X-ray diffraction was performed at 40 kV and 40 mA using copper radiation.

RESULTS

The as-HIP microstructures of the MERL 76- Low Carbon Astroloy combination are shown in figure 2. The interfaces between the alloys are plainly visible and the individual particles in the mixed powders retain their microstructural identities. Similar observations were noted for the other alloy combinations and are therefore not shown in figures.

The prolonged exposure of 1500 hours at 870° C did not cause any unexpected changes in the microstructure of any alloy combinations (compare figs. 3 and 2). Metallographic examination at still higher magnification, revealed no new phases in any of the alloy combinations (see fig. 4). As expected, the fine gamma prime particles had coarsened somewhat.

X-ray diffraction analyses after the prolonged exposure showed very weak indications of sigma phase in all of the base alloys, except NASA-TRW-VIA. Even weaker indications of sigma phase were detected in the mixed alloys. Even after exposure in a thermal gradient which exceeded the incipient melting temperature of one component alloy, the alloy combinations were stable. The microstructures shown for the MERL 76-Low Carbon Astroloy combination in figure 5 after a one hour exposure to approximately 1245° C and 1185° C are typical for all the combinations tested. Metallographic examination at the magnification shown in figure 5 and also at greater magnifications indicated that no new metallurgical phases were formed at the interfaces or in the diffusion zones. The MERL 76 - Low Carbon Astroloy combination was also

evaluated in a parallel contractual program (ref. 1) aimed at developing the technology for dual disks; here, no detrimental phases were detected at the sample interfaces during a variety of solutioning and aging heat treatments.

CONCLUDING REMARKS

The four alloys used in these combinations are not generally regarded as sigma-prone. Electron vacancy (N_V) calculations for mixed compositions predicted no tendency toward sigma formation and the N_V numbers were intermediate to those of the base alloys. But, X-ray diffraction showed that in 3 of the 4 alloys some sigma phase did form, although the indications were never more than weak. Since even examinations at high magnifications revealed no acicular phases it can be assumed that sigma is present only as small, discrete particles or a very fine discontinuous grain boundary precipitate. In this form its effect on properties is small (2). Furthermore, this stability test was purposely conducted at a temperature known to accelerate sigma formation (3), but well above that projected for even the most advanced turbine disks. The tests give considerable assurance that, using sigma-free alloys, deleterious phases will not appear in combinations of those powders in dual alloy turbine disks during HIP, heat-treatment nor at operating temperatures. This has been demonstrated for interfaces as well as for intimately mixed powders. It should be emphasized, however, that while these microstructures appear sound it should not be implied therefrom that the mechanical properties will be satisfactory. Actual mechanical tests of candidate alloy combinations should be performed.

SUMMARY OF RESULTS

The microstructures of hot isostatically pressed combinations of prealloyed powders of MERL 76 and Low Carbon Astroloy, René 95 and Low Carbon Astroloy, René 95 and NASA-TRW-VIA were examined in various conditions: as-HIP, after exposure at 780° C for 1500 hours and after heating up to 1300° C in a thermal gradient.

It was found that all alloy combinations:

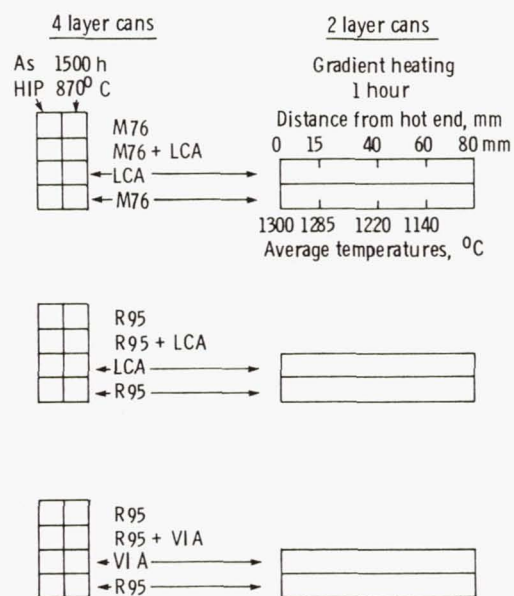
1. Remained free of unique phases at the interfaces and diffusion zones,
2. Underwent coarsening of the gamma prime phase during long time exposure to 870° C, and
3. Retained distinguishable structures in contacting particles of different compositions.

REFERENCES

1. Kortovich, C. S.; and Marder, J. M.: Development of Materials and Process Technology for Dual Alloy Disks. (TRW, Inc.; NASA Contract NAS3-21351) NASA CR-165224, 1981.
2. Dreshfield, R. L.; and Ashbrook, R. L.: Further Observations on the Formation of Sigma Phase in a Nickel-Base Superalloy (IN-100). NASA TN D-6015, 1970.
3. Mihalisin, J. R.; Bieber, C. G.; and Grant R. T.: Sigma - Its Occurrence, Effect and Control in Nickel-Base Superalloys. AIME Trans., vol. 242, 1968, pp. 2399-2414.

TABLE 1. - ANALYZED COMPOSITIONS AND SIEVE ANALYSES OF ALLOYS

	Low Carbon Astroloy	MERL 76	René 95	NASA-TRW-VIA
<u>Weight Percent</u>				
Ni	Balance	Balance	Balance	Balance
C	0.047	0.028	0.059	0.13
Cr	14.99	11.95	13.49	5.92
Mo	5.00	3.04	3.42	2.05
Ti	3.45	4.16	2.57	1.01
Al	4.05	5.13	3.65	5.27
Co	17.09	18.11	7.90	7.46
Cb	-	1.45	3.70	0.47
W	-	-	3.38	5.92
Ta	-	-	-	8.97
B	0.028	0.018	0.009	0.020
Zr	0.01	0.06	0.058	-
Re	-	-	-	0.32
Hf	-	0.43	-	0.38
Fe	0.12	0.14	0.33	0.13
<u>Percent Powder Fraction</u>				
- 80 + 100	10.7	12.7	7.7	
-100 + 140	17.0	22.7	13.1	1.0
-140 + 200	17.7	20.8	16.7	17.1
-200 + 230	11.6	5.8	9.9	13.6
-230 + 325	14.5	15.5	15.5	27.1
-325	28.5	22.5	37.1	40.8



Alloy codes:

M76 MERL 76
R95 René 95
LCA Low carbon Astroloy
VI A NASA-TRW-VI A
+ combination of 2 compositions
mixed in equal proportions

Figure 1. - Alloy combinations and test layout.



MERL 76

—— Interface



Mixed
MERL 76
+
low carbon
Astroloy

—— Interface



Low carbon
Astroloy

—— Interface

MERL 76

200 μ m

Figure 2. - Microstructures of as-HIP interfaces of the successive layers in a 4-layer can.

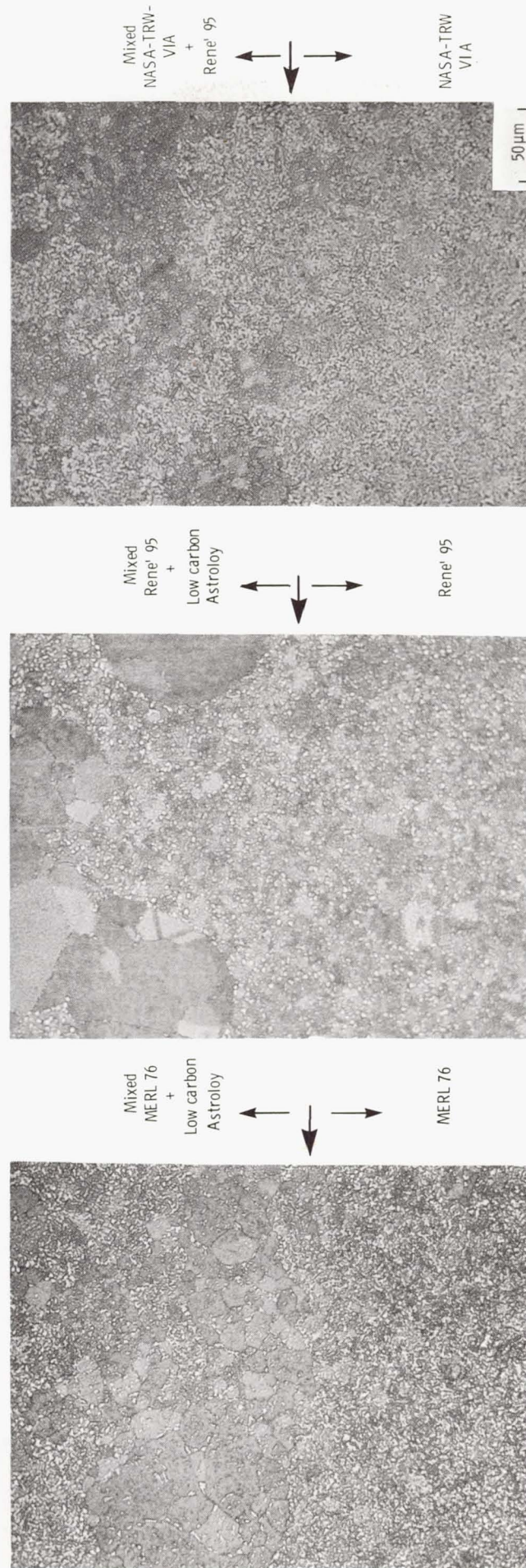
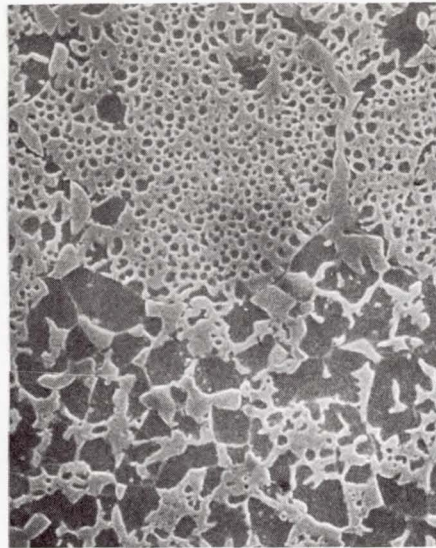
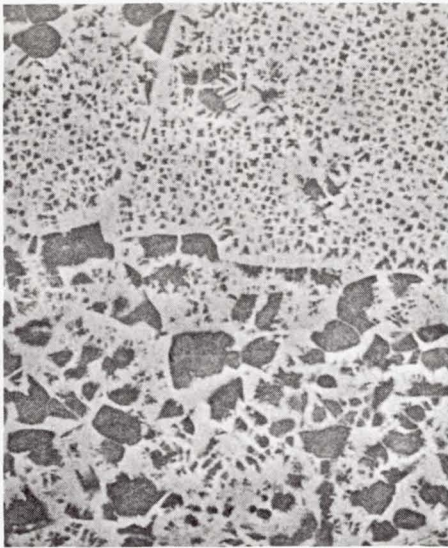


Figure 3. - Microstructures of HIP interfaces between layers of mixed alloy powders (top) and a single composition powder after holding at 870°C for 1500 hours.

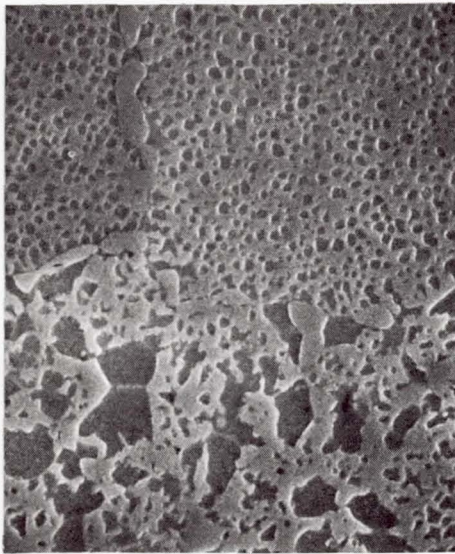
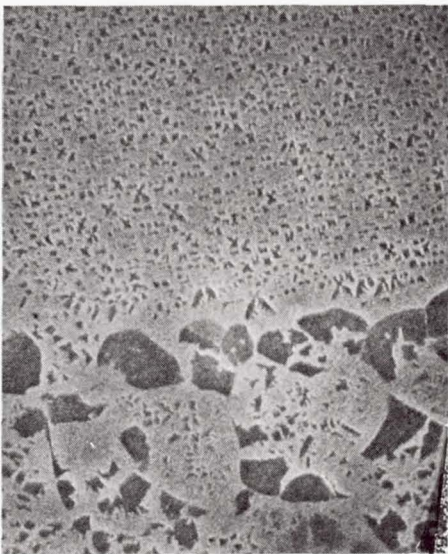
As HIP

Exposed



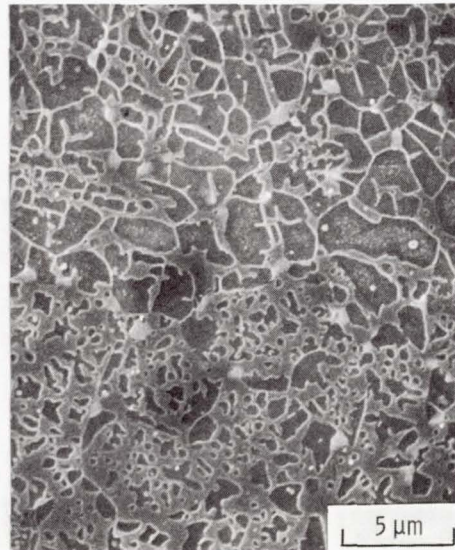
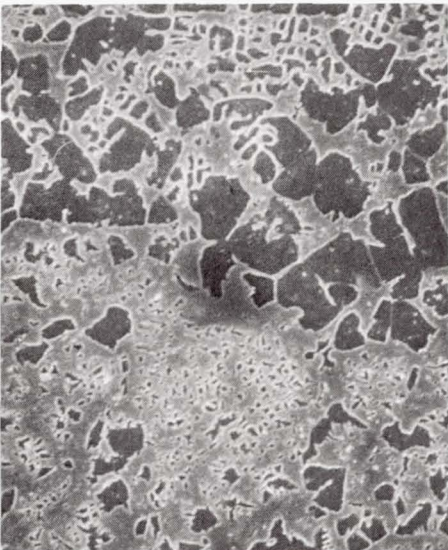
Low carbon
Astroloy

MERL 76



Low carbon
Astroloy

Rene' 95



NASA-TRW-VI A

Rene' 95

Figure 4. - Scanning electron micrographs of alloy combinations in as-HIP condition and after exposure at 870°C for 1500 hours.

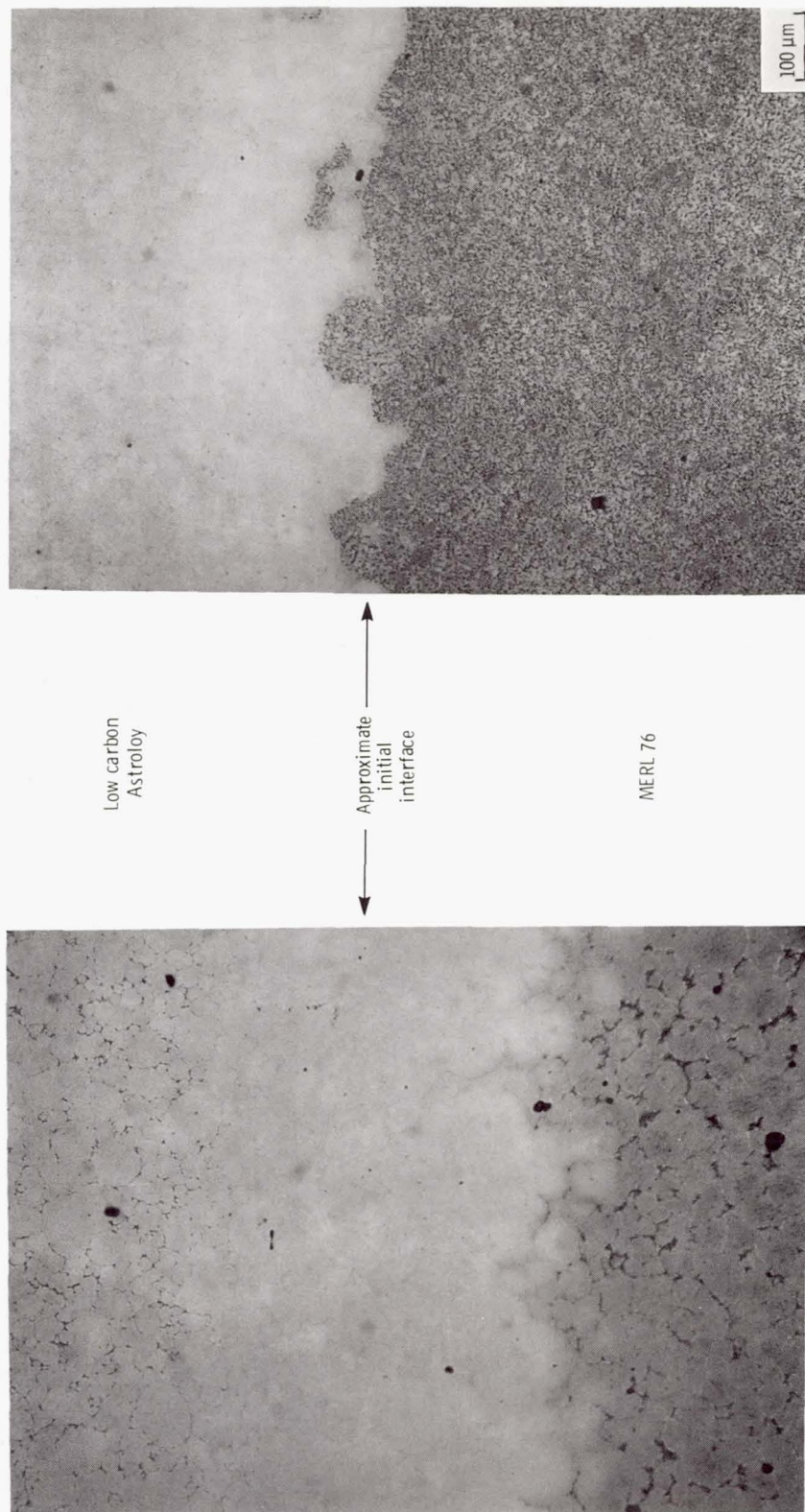


Figure 5. - Microstructures of interfaces of hot isostatically pressed powders after one hour exposure in a gradient furnace.

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